

Second Statement of David Blundell in Support of Proposed Class 21

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The opponents are simply wrong when they claim that vehicle owners are too stupid to improve on their cars without violating emissions laws or compromising safety. That is ridiculous and in order to illustrate, I'll provide a few examples. All of these are well-known modifications known to many tinkerers.

1. Optimizing Transmission Shift Patterns

An engine's efficiency varies considerably across different load conditions as well as speed(RPM). With virtually no exceptions, engines are more efficient at higher loads, all else aside. Engines typically have a narrow RPM range (10-25% of their operating range) in which they are most efficient. Engines are almost always attached to transmissions which exchange vehicle speed for torque using gears. Most cars in USA feature automatic transmissions and "lockup" torque converters under computer control, allowing a transmission control computer to make decisions to optimize operation for economy or acceleration.

There are two basic "behavioral" things at play: what gear the transmission is in and whether the torque converter is locked. What gear the transmission is in is arguably more intuitive. The "gear ratio" is the relationship between the speed of the engine and the speed of the wheels. Changing to a different gear allows the motor to operate at a different speed while maintaining the same wheel speed.

Shifting from a lower to a higher gear requires an increase in torque output to maintain a constant speed. Higher torque output necessitates higher load on the motor. Higher load usually means higher fuel efficiency. Higher gears generally mean lower motor speed (RPM) and higher fuel efficiency. Higher gears mean less torque multiplication, which means that there will be less vehicle acceleration from a given amount of engine torque output.

There is almost always guaranteed to be at least 2 possible gears to achieve a given speed at any time. By choosing between them, you can affect fuel economy. Transmissions can be used to keep a motor in its optimum RPM range for fuel economy by choosing higher gears that place the motor under heavier load where it operates more efficiently. However, the choices made in order to increase fuel economy are generally not optimal for performance because they multiply torque less than lower gears.

There is no single perfect pattern of upshifts and downshifts because there are inherent compromises between "peppiness" and fuel economy inherent in gear selection. There is a considerable amount of subjective "feel" that can vary from different shift pattern arrangements that exists independent of any objective metric. This transmission shift point manipulation is fair game for the tinkerer, who can optimize for intended vehicle use without compromising emissions or safety.

2. Optimizing Torque Converter Lockup Pattern

Torque converters are a fluid coupling linking the engine and the transmission. Imagine two fan blades sitting right next to each other in a vat of molasses. When one fan blade spins, it moves the fluid which pushes the other fan blades and makes it try to spin. This is the "unlocked" state of the torque

converter. It can act as a torque multiplier during times where the two fans are moving at different speeds. Generally speaking, there are larger losses with fluid coupling than direct coupling, hence the motivation for locking converters. "Lockup" converters allow the fluid coupling to be exchanged for a 1:1 direct drive mechanical coupling, under computer control.

Typical operation:

- Start off with converter unlocked so motor doesn't stall when vehicle is stopped
- Driver applies throttle, torque into the converter increases
- Converter "slips" allowing the motor to spin faster than the converter's output, multiplying torque output as the input speed increases faster than the output
- Motor accelerates into a higher RPM range where it produces good torque and operates efficiently
- While motor maintains constant RPM, converter output speed "catches up" with its input speed (motor RPM) and as this happens, torque multiplication decreases as output speed catches up
- Electronic lockup converters add the ability to ditch this fluid coupling mechanism in lieu of direct coupling in which there is no torque multiplication but also lower losses
- If the motor is in an optimum RPM range for efficiency, locking the converter will decrease transmission losses and allow more torque to be transmitted from the engine to the transmission, increasing efficiency by decreasing losses from hydraulic coupling in the torque converter
- Locking the torque converter removes any torque multiplication, which will make the motor feel slower because there is no torque multiplication by the converter.

There is no single "perfect" torque converter lock/unlock pattern. Every scenario will be a compromise between fuel economy, acceleration, Noise-Vibration-Harshness(NVH) and subjective feel. There is often considerable room for improvement in fuel economy by controlling converter lockup in a different pattern than factory without compromising emissions or vehicle safety.

I have routinely been able to achieve 1-2mpg increase in fuel economy from shift pattern and converter lockup programming without changing engine operation at all. On a pickup truck that gets 10-12mpg, 1-2mpg is a big deal especially when it comes without durability or emissions penalties. I accomplish this without violating emissions laws, compromising safety, or damaging parts.

3. Optimizing Engine Cylinder Pressure

My next example requires me to explain at a basic level how engine cylinders work. Piston engines (both gas and diesel) use energy from combustion of fuels to operate. This energy is harnessed by creating pressure inside the combustion chamber of each cylinder of an engine., termed cylinder pressure.

Cylinder pressure pushes down on pistons. This force is transmitted through rods connected to a crankshaft. Pistons exert a mostly linear force (as they are pushed down the bore) on the crankshaft. In order for cylinder pressure to be transformed into torque, it needs to occur at the right time so that the peak force (cylinder pressure) on the connecting rod occurs when it is pointed "right"(tangential)

to the crankshaft. When this happens, the rod pushes the crankshaft the correct direction to maximize mechanical advantage and the most cylinder pressure force is transformed into usable torque.

If force occurs too early, some of the force is wasted by pushing the crank in the wrong direction. It is even possible that it could happen so early that the force is applied counter-rotation and produces only "negative" torque. If the force occurs too late, the crankshaft is moving in a different direction than the force is being applied and again a portion of the cylinder pressure fails to be converted to torque.

One of the major functions of engine computers is to optimize this cycle by controlling combustion so that the most cylinder pressure possible is turned into usable torque without waste.

If you want to increase the torque/horsepower output of an engine, one of the obvious choices is to increase cylinder pressure: cylinder pressure turns the crank. More cylinder pressure means more turning the crank, means more torque.

If you want to increase the fuel economy of a motor, you must produce the same amount of torque in given conditions using LESS fuel. A more fuel efficient motor will almost always achieve more cylinder pressure with a given amount of fuel than a less efficient one.

However, more is not always better. In addition to potentially physically destroying engine components, high cylinder pressure also can produce pollution. Putting nitrogen and oxygen together under high enough pressure and heat will bond to form various nitrogen oxides, some of which can further chemically react to form nitric acid, one component of acid rain pollution. Notice "high enough" - there is a threshold under which NO_x formation is relatively negligible – it is not guaranteed to happen. High enough cylinder pressures with a "lean" condition (i.e. combustion conditions with an abundance of oxygen relative to fuel) are particularly favorable for the formation of nitrogen oxides.

Most of the "other" pollutants (HC - hydrocarbons, CO - carbon monoxide) happen mostly in "rich" conditions where there is an abundance of fuel compared with the amount of oxygen entering the engine. These pollutants (broadly speaking) are the result of too much fuel being present or incomplete or inefficient combustion. Catalytic converters process pollutants from inefficient combustion and attempt to "finish" combustion, resulting in CO₂ and H₂O instead of poisonous and undesirable CO and HC. Oxygen sensors allow ECUs to monitor combustion conditions and apply feedback. Engine computers generally use oxygen sensors to guide engine operation into a range favorable for catalytic converters to produce low emissions. HC/CO emissions can generally be effectively controlled by the combination of physical measures (catalytic converters) combined with feedback systems on the ECU.

Now that we've examined what kind of emissions happen under which conditions, let's examine what would need to happen on a physical level to increase fuel economy and consider its impact on emissions.

Common sense answer: in order to increase fuel efficiency, (in a given set of conditions) the same amount of torque would need to be generated from LESS FUEL.

Tinkerers seeking fuel economy will need to decrease the amount of fuel being used. This generally means that they will be using a LEANER mixture, one where the formation of HC and CO emissions is LESS LIKELY. Therefore, the only emissions that are likely be INCREASED by using LESS FUEL are going to

be NOx emissions that happen primarily under the same lean conditions which favor fuel economy.

Unlike the assertions made by opponents, increasing emissions is not a guaranteed outcome of increasing fuel economy. For tinkerers to increase fuel economy without increasing emissions simply requires them to produce a net gain in cylinder pressure using a given amount of fuel without exceeding the threshold necessary for the rapid formation of Nox pollutants.. This is far from impossible to do.

In many cases, changing from 87 to 91 or 93 octane allows operating the motor in conditions which would have produced physical damage originally. Operating the engine with more cylinder pressure made possible through increased octane fuel is a simple and common way to increase fuel economy. Many OEMs build strategies into engine computers to dynamically adjust engine operating conditions by “sensing” the octane fuel present. When these strategies are absent (as is often the case in older cars) or simply fail to realize the full potential of a change in fuel, tinkerers have a golden opportunity to tailor changes more precisely and realize further economy gains while maintaining emissions compliance.

Further, the use of higher-octane fuel may not always be necessary. Car companies always leave a cushion between conditions created by factory programming and conditions harmful to the engine or prone to create emissions. As long as the engine was not already on the edge of forming NOx, it will be safe to increase cylinder pressure without significantly increasing emissions. Operating within this safety margin allows tinkerers the opportunity to operate within the law without the need to change fuel.

Finally, the existence and availability of aftermarket parts muddies waters – the aftermarket is huge and is not going anywhere anytime soon. When people install aftermarket parts, if they’re NOT able to reprogram vehicle computers then the new part can cause problems with emissions, power output and reliability. After appropriate modifications were made to the engine computer, proper vehicle operation can be restored and sometimes even improved. Many aftermarket parts, such as a cold air intake which allows air to enter the engine with less restriction than a factory airbox, can improve the overall efficiency of the engine. In fact, some come as factory equipment on emissions tested vehicles (i.e. intake on 2008 Mustang Bullit) and are also sold as “aftermarket” by Ford Racing. Obviously, OEMs could have fitted similar parts to those available in the aftermarket but design considerations such as noise or cost can prevent them from doing so. It is entirely possible for aftermarket parts to improve vehicle operation without negatively impacting emissions but only when computer programming tools currently in gray territory under the DMCA are available to properly program the computer! Oh the irony!

Keep in mind that prior to computerized cars, any mechanic was guaranteed to be able to make mechanical adjustments to optimize a vehicle's performance. Application of the DMCA to computerized engine control systems raises doubts as to whether future mechanics will have the same options available as in the past. Engines can always be modified to use a carburetor, losing the many benefits of modern electronic computer controls. Does it benefit anyone to push tinkerers in this direction?

Opponents’ Other Arguments About Safety Are Equally Misguided

If the opponents were right about the scale of safety concerns, the NHTSA would have tried to outlaw

tinkering on your own car long before the DMCA. There are many complex systems in a car with profound safety consequences which have been open to modification for many years without any publicized malicious attacks that required circumvention. Vehicle regulators fortunately have not caved in to the use of scare tactics aimed at eliminating lawful modifications.

Let's look at the airbag example raised by opponents. There are cases where it's lawful and even a good idea to disable airbags, such as cars with roll cages used for racing where airbags would do more harm than good if they deployed. Disabling airbags does not require circumvention – many safety systems can be disabled simply by unplugging a fuse. You can disable the resulting warning light by snipping a wire or removing the indicator bulb. DMCA prohibitions don't hinder these “dangerous” modifications.

There are many people who know how to bypass access controls, and I have never heard of a vehicle seller bypassing a protection mechanism to hide a disabled safety system in order to deceive a buyer. Disabling error reporting does not require circumvention prohibited by the DMCA. Someone could just remove the bulb for the check engine light. Opponents worry about many such things that are much easier to accomplish *without* circumventing, i.e. the old fashioned way. Criminals can cut a brake line in less than ten seconds with only exterior access to the vehicle, causing a potentially fatal loss of braking. A cheap “bug” can be planted in a car to record and transmit conversations far easier than reverse engineering a Bluetooth-enabled stereo. GPS tracking can be trivially accomplished with an unmodified smartphone far easier than reverse engineering a built-in GPS unit. While opponents suggest that modified cars could spread viruses to dealers with a tremendous amount of sensitive consumer data, poorly engineered insecure dealer networks are not the responsibility of the automotive tinkerer. Viruses from email and USB sticks actually happen today yet dealers aren't unplugging the internet and banning iPods, even though these are far more likely than a modded car to infect sensitive dealership PCs. Over and over we see that the DMCA isn't being relied on to decrease mischief because it is easier without circumventing protection measures.

Further, DMCA prohibitions harm vehicle security by restricting concerned organizations and individuals ability to inspect, analyze, reverse engineer and extend. Allowing reverse engineering would provide a strong impetus for proper implementation of strong crypto in vehicles. Without these researchers, user options are limited to those provided by the OEM or “authorized parties” with no independent auditing or quality control. The Toyota unintended acceleration deaths probably could have been avoided by peer code review. (the Barr Group found bugs) DMCA vehicle security protections don't help the consumer – they're being misused to attempt to exclude participation in the market.

Publicizing mechanical improvements or repairs to a vehicle does not face the same legal cloud that the DMCA creates over sharing code modifications to a vehicle. This double standard makes little sense in light of the growing role of digital systems in the operation of automobiles and will only hamper the continued growth and development of the market for information related to automotive systems.

I urge the Copyright Office to grant the proposed exemption to protect legitimate tinkering and not be swayed by the misguided fear-mongering of the opponents.